EVALUATION OF THE USEFULNESS OF THE MOL TO ACCOMPLISH EARLY NASA MISSION OBJECTIVES (u)

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VOLUME I
SUMMARY

OCTOBER 1967
DAC-58060

DOUGLAS
MISSILE & SPACE SYSTEMS DIVISION

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SUMMARY

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Submitted by:
Douglas Aircraft Company

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DOUGLAS MISSILE & SPACE SYSTEMS DIVISION

FRONTISPIECE

The MOL-derived space station for NASA missions is represented by the Double MOL configuration illustrated here. This space station provides a facility to determine man's utility in the performance of meaningful engineering and scientific experiments in a weightless environment. It is composed of two vehicles (a Laboratory Vehicle and a Support Vehicle), uses the basic Air Force MOL, with these modifications required to extend its time on orbit to 1 year.

The Laboratory Vehicle contains the primary experiment package and control stations and supplies the electrical power for the entire mission. It is launched on a Titan III-M and consists of a Gemini B, a Laboratory Module, and a Mission Module.

The Gemini B re-entry vehicle is maintained in a passive mode during orbital operations and is separated from the habitable Laboratory Module by an unpressurized compartment which houses the reaction control subsystem, crew transfer tunnel, and contingency supply of water and atmosphere.

The Laboratory Module provides the primary control stations, and also contains the spacecraft control station, experiment control station, experiment airlock, emergency sleeping and eating facilities, hygiene facility, and biomedical-behavioral experiment packages.

The Mission Module contains the engineering and scientific experiments, crew transfer tunnel, airlock, docking structure, an experiment mounting beam, and a solar panel/electrical subsystem.

The Support Vehicle, launched on a Titan III-M, remains in orbit for 6 months and is replaced by a similar vehicle; it consists of a Gemini B, living quarters, and a Mission Module. The pressurized compartment contains sleeping, eating, and hygiene facilities for 4 men and the backup spacecraft control station.

The Mission Module contains a telescope module along with a variety of engineering, scientific experiments, crew transfer tunnel, airlock, and docking structure and provides the expendables to support the entire spacecraft for 6 months.

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PREFACE

This report is submitted to the National Aeronautics and Space Administration's Manned Spacecraft Center (MSC) by the Douglas Aircraft Company. The report was prepared under Contract No. NAS9-6798 and describes the results of the Study to Evaluate the Usefulness of the MOL to Accomplish Early NASA Mission Objectives, which was performed during the period of 20 February to 4 October 1967. The purpose of this study has been to establish the feasibility of adapting and extending the USAF Manned Orbital Laboratory (MOL) to a 1-year space station.

The final report consists of two volumes; these are Volume I, Summary, Douglas Report No. DAC-58060 and Volume II, Technical, DAC-58061. Furthermore, Volume II, because of its size, was divided into Books 1, 2, and 3, all of which carry the same Volume II report number. The Appendix (Douglas Report No. DAC-58062) contains data of a higher classification than the report; therefore, its distribution will be limited and controlled by MSC.

The results of the Phase I, MOL System Definition, have been previously published in separate reports (Volumes 1 through 8, DAC-58013 through DAC-58020) and are not repeated in this report.

Requests for further information concerning this report will be welcomed by the following:

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During this study, the Douglas Aircraft Company was associated with several subcontractors whose contributions were used to synthesize and evaluate the MOL subsystems. These subcontractors are listed in alphabetical order below.

Allis-Chalmers--Research Division
Electro-Optical Systems, Inc. --Power Systems Division
Fairchild-Hiller--Space Systems Division
Honeywell Corporation--Aerospace Division
North American Aviation, Inc. --Rocketdyne Division
Radio Corporation of America--Astro-Electronics Division
Ryan Aeronautical Company--Electronics and Space Systems
The Marquardt Corporation
TRW Systems--Electric Power Laboratory
United Aircraft Corporation--Pratt & Whitney Aircraft Division

CONTENTS

Page Not Available

FIGURES

TABLES

Section 1

INTRODUCTION

The nation's manned spaceflight program has progressed through a series of missions beginning with the Mercury program, followed by the Gemini program and through the early phases of the on-going Apollo program. Definition of subsequent manned spaceflight activities is currently underway. All feasible alternatives will be studied in the definition task to ensure meaningful and cost-effective mission/system choices.

During the past several years, NASA has studied a number of candidate system concepts for the long-duration, Earth-orbital missions. These concepts, typified by MORL, LORL, and modular space-station approaches, derived their background primarily from Saturn/Apollo equipment. More recent efforts have emphasized definition of an Apollo Applications Program using potentially excess Saturn/Apollo hardware from the lunar program.

A fruitful alternative to this early, or interim, Earth-orbital mission would consider the use of the Air Force MOL, which is conceived and designed as an Earth-orbital experimental vehicle. This approach recognized by both the NASA and the President's Scientific Advisory Committee (PSAC) led NASA to undertake this limited investigation of the utility and feasibility of using MOL derivatives to perform early NASA missions. This report summarizes the results of a feasibility study of the NASA usage of MOL which was conducted by the Douglas Aircraft Company under contract to Manned Spacecraft Center (MSC).

The evaluation of the usefulness of MOL to accomplish the early NASA mission objectives asks three basic questions: (1) Could the MOL with relatively minor modifications perform the NASA 1-year biomedical/behavioral assessment of man and his capabilities in a zero-g/space environment? (2) Could the same modified MOL vehicles in addition to accomplishing the biomedical/behavioral assessment provide the facility for a broad spectrum

of engineering and scientific experiments? (3) Could such a program be accomplished at an early date without interfering with the basic MOL and Saturn/Apollo programs?

Although no NASA-approved biomedical/behavioral program exists at this time, Douglas has designed a representative program to accomplish the first objective; this program has been reviewed by the various NASA agencies and is recognized as a reasonable approach to the problem with adequate depth to ensure compatibility with the final program selection. The equipment required for this activity has been conceptually designed, and in some cases breadboarded, and integrated into the NASA/MOL conceptual design.

To assess the capability of MOL to accomplish a broad spectrum of engineering and scientific experiments, use was made of NASA's most recent experiment data bank developed in the S-IVB station module study. The major space station resources available (weight, volume, power, crew skills, and crew time availability) permit accommodation of almost any experiment considered singly. 35% of the heaviest experiments or up to 80% of the data bank experimentation could be accomplished in a one-year NASA/MOL type mission.

Because the MOL production line was designed for an appreciably higher rate of activity than is currently planned by the Air Force, it is possible to procure the requisite MOL hardware and modify it within the requested time scale; this can be done at a very moderate cost in new facilities and equipment, most of which will be related to the experiment program rather than to the mission vehicle.

In summary then, it is concluded that use of MOL-derived hardware is conceptually feasible and cost effective in accomplishing early NASA objectives. The program would be primarily dependent on two external circumstances: (1) timely program implementation decisions, and (2) availability of appropriate experiment hardware.

Section 2
STUDY PLAN

The subject study, which was begun in February 1967, was conducted in two phases; the purpose of the first phase was to provide NASA with a definition of the basic MOL system and an understanding of the design and limitations of the subsystems involved. These data were then used to evolve appropriate design for a 1-year space station. Results of this phase of the efforts were published in an earlier report consisting of eight volumes; these volumes included DAC-58013 through DAC-58020, May 1967.

Phase II of the study effort studied a requirements analysis and space-station configuration development task early in the program. During this effort ten space-station configurations were evolved and evaluated to the defined requirements; these configurations were evaluated jointly with NASA at the end of Phase I and two configurations were selected for detailed analysis. A cursory examination of the applicability of MOL subsystems to space station utilizing the Mission Core Module (engine room) concept was also undertaken. Finally, an assessment of the responsiveness of the developed configurations to performance of NASA experiment program defined in the S-IVB support module study was conducted. The results of this effort are reported in this volume and the accompanying Douglas report, Volume II, DAC-58061, October 1967.

2.1 BASELINE MOL

The basic MOL vehicle is illustrated in Figure 2-1. Gemini B is used to transport the two-man crew into space and to provide return at the end of the mission, is launched on top of an unpressurized compartment that contains the MOL fuel cell power system, the EC/LS system expendables, the reaction control system and propellant package, and the cryogenics necessary for the mission for both the power system and breathing usage. A transfer tunnel is provided through this

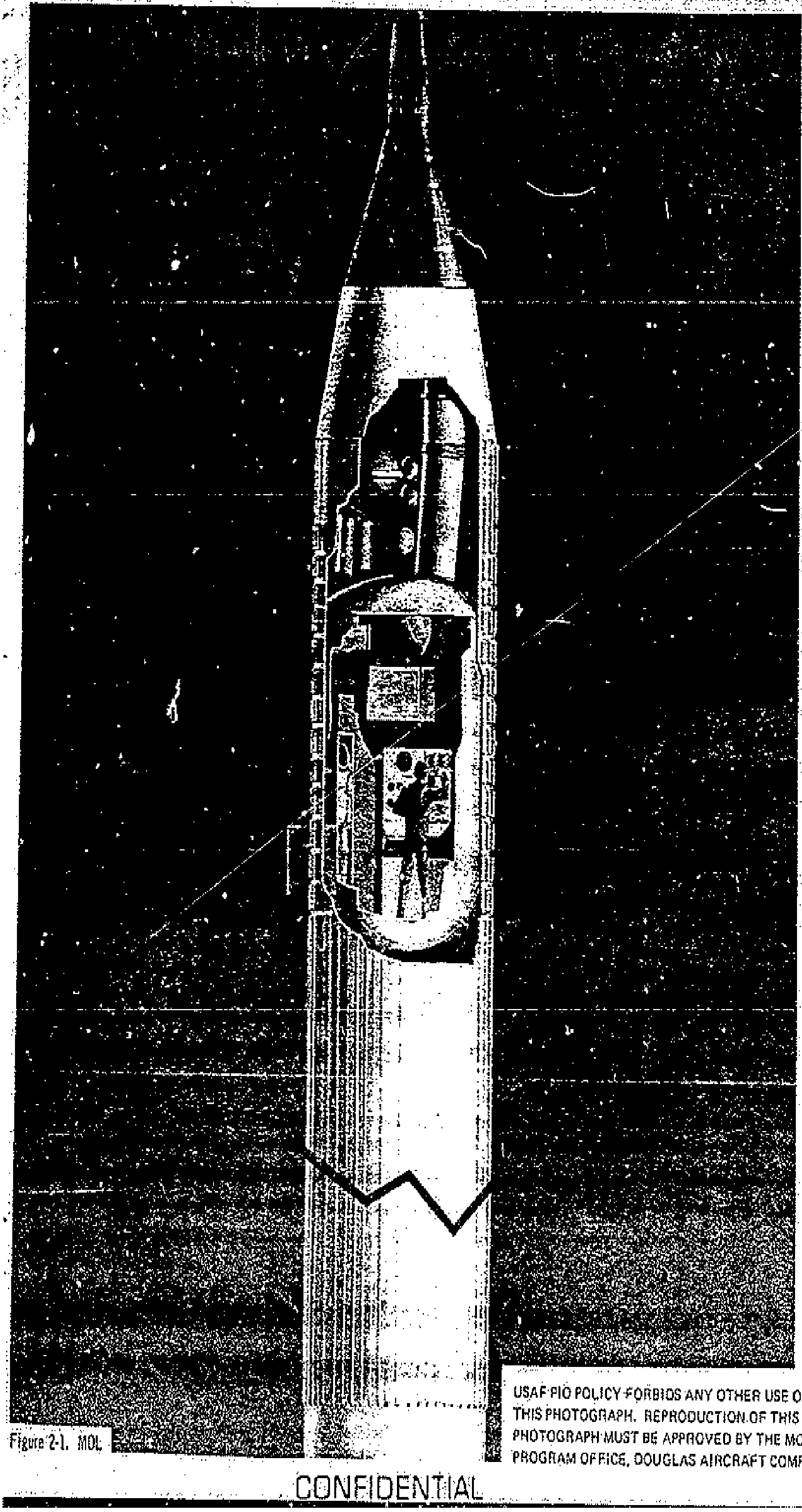

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Figure 2-1. MOL

unpressurized compartment to allow the crew to move from the Gemini to the MOL laboratory compartment after attainment of orbit. When the crew transfers from the Gemini, it is put in a standby mode where it is maintained at minimum power and at approximately 0.1 psi until the end of the mission.

The pressurized laboratory compartment is 14 ft in length and provides crew quarters for the duration of the Air Force mission. This compartment also contains the space station operational controls, the consoles, and the control equipment for the experimental program and provides the necessary crew support equipment for exercise, crew hygiene, eating, and sleeping facilities. Emergency EVA from this compartment is provided through a hatch in the pressure compartment; this hatch allows the crew to exit from the laboratory and re-enter the Gemini through the side access door in event of internal tunnel blockage.

The segment of the vehicle between the pressurized compartment and the Titan III-M launch vehicle is the mission module which contains Air Force experiment equipment. In the basic MOL, neither the forward unpressurized subsystem compartment nor the mission module are accessible to the crew for maintenance or support activities.

2.2 MISSION REQUIREMENTS

Table 2-1 presents a comparison of the mission requirements for the NASA/MOL operation compared to those of the basic Air Force mission. The three requirements which had the most impact on this study were (1) the 1971 launch date which established a minimum-change philosophy for subsystem selection and vehicle design, (2) the change in mission duration from 30 days to 1 year, and (3) the expansion of the crew size from 2 to 4 or 6 men.

In line with the minimum-change philosophy, many desirable improvements which could have been incorporated were rejected if they were not essential to mission success; sufficient launch vehicle payload existed to accomplish a significant portion of the total NASA objectives allowing a majority of this class of improvements to be carried as alternatives. The mission duration required that special emphasis be put on subsystem reliability assurance and provisions for in-orbit repair and maintenance. Since the

baseline MOL has minimal provisions for spares and maintenance, subsystem equipment repackaging was required in addition to redundancy within the inaccessible compartments.

Other requirements of special interest were the KSC launch and compatibility of the vehicle with the NASA MSFN and Houston operational facilities.

Table 2-1
MISSION REQUIREMENTS COMPARISON

	AF MOL	NASA MOL
MISSION	MILITARY	BIOMEDICAL/BEHAVIORAL & BROAD SCIENCE/EXPLOITATION
FLIGHT DATE	— —	1971
DURATION	30 DAYS	1 YEAR
CREW SIZE	2 MEN	4 TO 6 MEN
LAUNCH SITE	WTR	ETR
LAUNCH VEHICLE	TITAN IIIM	TITAN IIIM OR SATURN IB
GROUND NETWORK	SCF	MSFN
ORBIT	HIGH INCLINATION	28 TO 70° INCLINATION / CIRCULAR
RESUPPLY	NONE	AS REQUIRED
ARTIFICIAL G	NONE	ASSESS PENALTIES

2.3 CONFIGURATION SELECTION

Of the ten potential MOL and MOL/Saturn Hardware configurations which were identified and briefly evaluated, three were chosen for further effort; these three configurations are indicated in Figure 2-2. The Double MOL configuration consists of two basic MOL vehicles suitably modified to perform the required mission utilizing a four-man crew. These vehicles are docked end-to-end in orbit and resupply of one of the vehicles at a 6-month interval is provided. It is the simplest, cheapest and lowest risk configuration.

The Saturn Workshop/MOL configuration combines an advanced spent-stage workshop, derived from the Apollo Applications Program (AAP) cluster concepts, with three MOL's suitably modified for mission accomplishment. It has a six-man crew and provides appreciably larger pressurized volume and flexibility than the Double MOL; it is as a consequence more expensive.

The Mission Core Module configuration, based on MSC's engine room concept, uses the basic module design under study by General Dynamics; this module is outfitted with MOL components insofar as possible. Analysis of this concept was limited to the applicability of MOL systems to this design; however, in order to assess its capability it was necessary to synthesize the typical orbital configuration indicated.

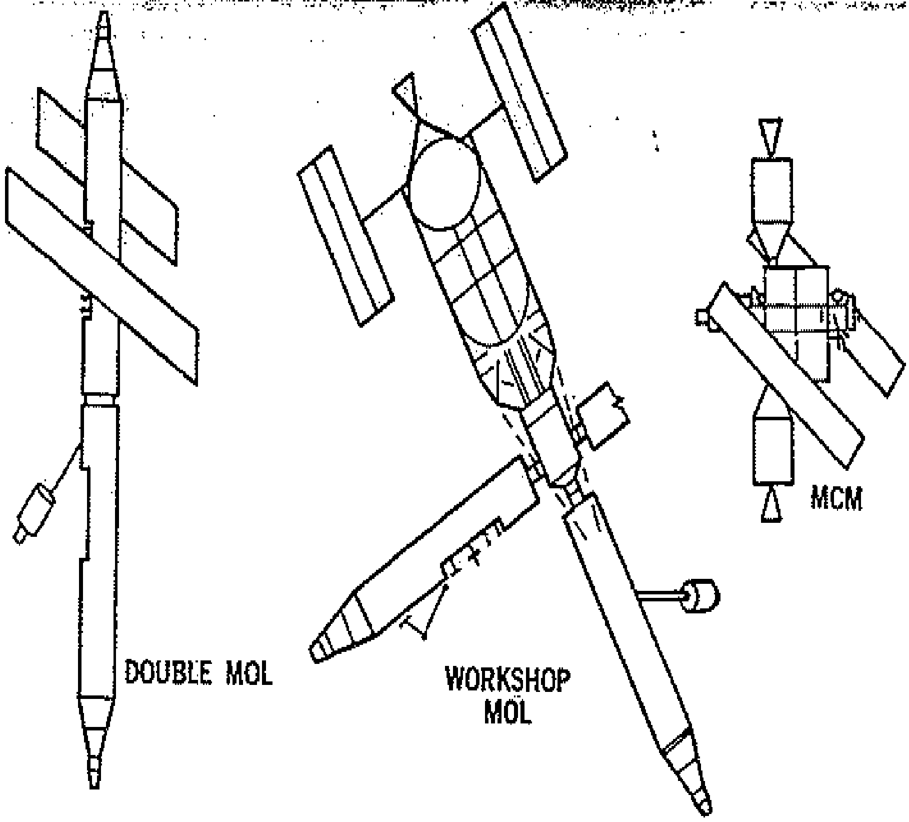

Figure 2-2. Configuration Summary

2.3.1 Double MOL Configuration/Mission

The Double MOL mission profile is depicted in Figure 2-3. A suitably modified MOL which we have designated as the Laboratory Vehicle is launched into a 195-nmi, 2-day subsynchronous circular orbit by the Titan III-M booster. This is accomplished using an apogee circularization technique to transfer the vehicle from an 80 by 195 nmi elliptical orbit to the final circular orbit; it allows a 7,000-lb payload increase over that available with direct burn into orbit.

After a nominal 2-day period corresponding to the subsynchronous orbit retrace, a second MOL vehicle, designated the Support Vehicle, is launched into a 100-nmi circular phasing orbit; it is then transferred to 185-nmi catch-up orbit from which it rendezvous and docks to the Laboratory Vehicle in the 195-nmi final orbit. This Support Vehicle contains the majority of the supplies and expendables necessary to maintain both vehicles in orbit for a period of 6 months. Both launches are accomplished with a manned Gemini B ferry vehicle as part of the payload, thus providing the Double MOL orbital vehicle with a four-man crew.

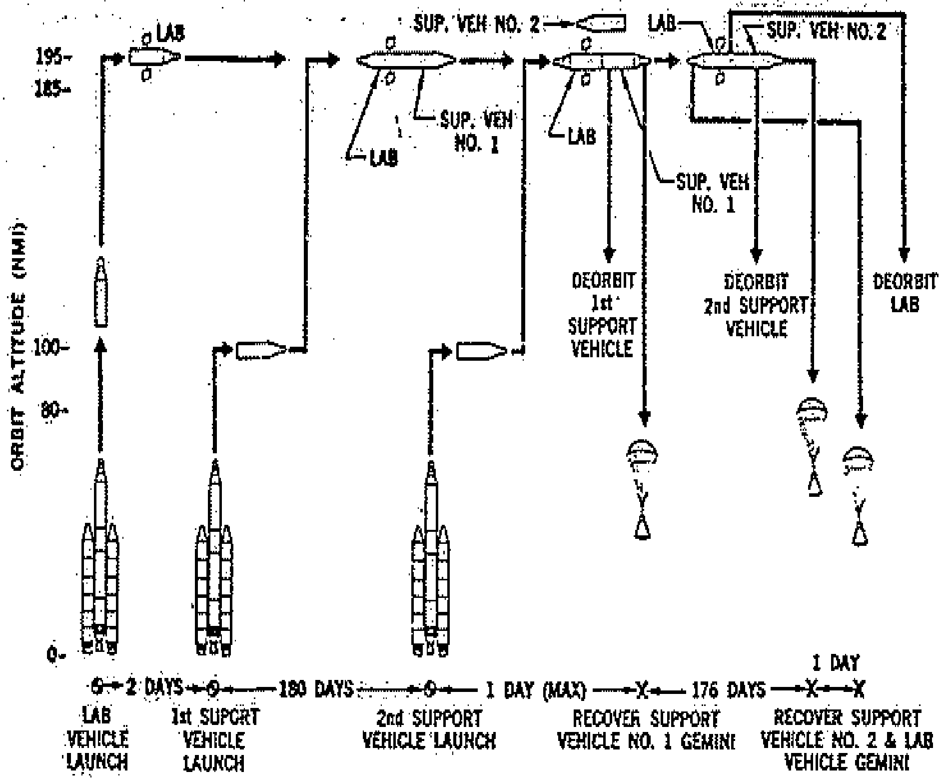

Figure 2-3. Mission Profile – Double MOL

At the end of the initial 6-month period the Support Vehicle supplies are nominally exhausted and a second similarly configured Support Vehicle is launched; it may, however, be outfitted with a new or modified experiment package. Prior to rendezvous of the new Support Vehicle with the Laboratory Vehicle the initial Support Vehicle is undocked and flies formation with the Laboratory Vehicle. Subsequent to docking of the newly orbited Support Vehicle with the Laboratory Vehicle, crew transfer may be accomplished. Thus, the newly orbited crew may remain with the laboratory allowing the return of two of the original crew members to Earth or they may return to Earth immediately; in any event, the original Gemini would be used to return two astronauts to Earth and the new Gemini would remain in orbit. Subsequent to the Gemini re-entry, the initial Support Vehicle would be deorbited into the deep ocean.

Upon conclusion of 1-year mission the four crew members would re-enter the two Gemini B vehicles remaining in orbit for return to Earth and the Laboratory and Support Vehicles would be deorbited into the deep ocean.

Consideration has been given to the potential of extending the mission beyond the original 1-year period by supplying a third Support Vehicle; preliminary reliability assessment indicates significant probability of success for such a mission extension and it should be seriously considered by NASA if the proposed MOL mission is implemented.

The MOL Laboratory Vehicle illustrated in Figure 2-4 retains the external geometry and dimensions of the baseline MOL. In the forward unpressurized compartment, fuel cells and storage for the associated cryogenics have been removed. A sufficient supply of oxygen and nitrogen is provided to give the Laboratory Vehicle the capability of operating in orbit without the Support Vehicle for 20 days.

A forward-facing, 100-lb thruster has been added to each of the 4 propulsion modules to provide aft translation capability and an additional set of propulsion fuel, oxidizer, and pressurant tanks are included.

In the pressurized compartment the internal birdcage equipment support structure has been retained for mounting of all equipment. The Air Force

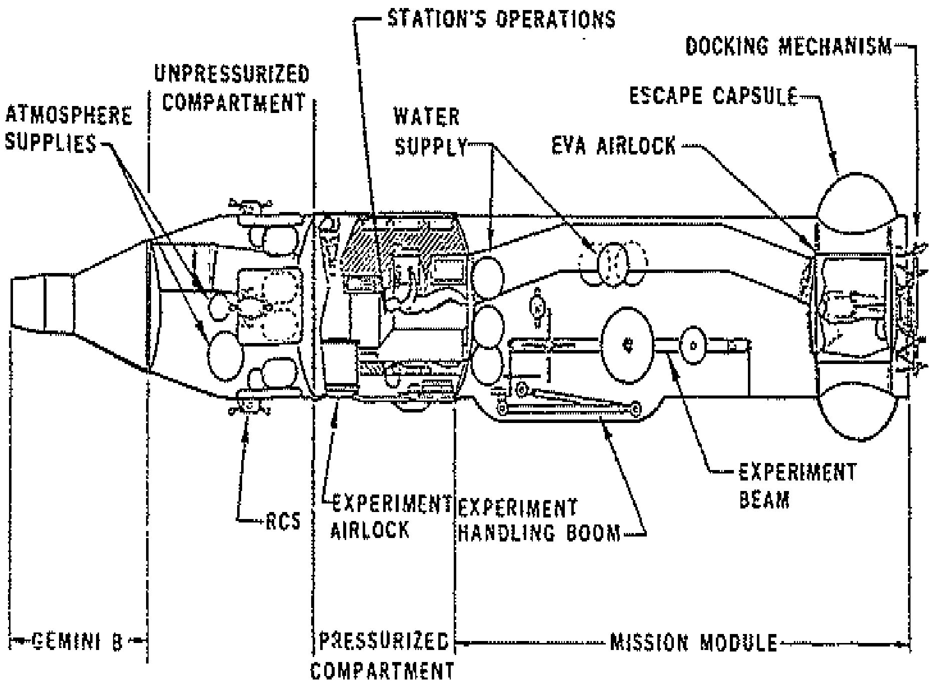

Figure 2-4. Double MOL Laboratory Vehicle

mission equipments and controls have been removed from this support structure and replaced by NASA experiment packages and controls and an integrated biomedical/behavioral package. Control of the orbital configuration is accomplished from this station. Provisions in this vehicle for eating, sleeping, and hygiene are used only during the first 30 days of the mission; these functions are supplied in the Support Vehicle for the long-duration stay time. An experiment airlock has been installed over the EVA hatch in a manner which does not eliminate this capability; this airlock permits small experiment packages to be handled externally with the aid of an experiment boom thus minimizing EVA requirements. Typically, cameras, small sensory packages, and test samples could be handled through this airlock in support of the experiment program.

The unpressurized mission module will be provided to the NASA program as an empty structure. It has been outfitted to contain the new solar panel/battery power system, remotely operable experiment equipment, crew transfer provisions, EVA airlock, and minimal stores and supplies. The aft crew transfer tunnel connects the pressurized compartment to the aft airlock which provides access to the experiment volume and through the docking structure to the Support Vehicle. It is located off-center to provide a maximum packaging volume for experiments and makes use of lengths of tunnel structure common to that through the forward unpressurized compartment in the baseline MOL.

An experiment sensor beam is provided to mount Earth-centered sensors, such as radar, IR, and microwave radiometers. The beam is located off-center and rotated 90° to permit installation of sensors on the ground. Subsequent to the boost phase, an experiment access door is removed exposing the beam which is rotated 90° to point the sensors outward; the beam can subsequently be returned to its original position for replacement or service of the sensors.

A new large-diameter docking mechanism is located on the aft of the vehicle and mates with an identical unit on the aft end of the Support Vehicle; the necessary change in separation plane between the mission module and Titan III-M is also indicated in Figure 2-4. Emergency, one-man, escape capsules which were supplied conceptually by MSC are mounted in the protrusions shown on the aft section of the mission module.

The solar-cell/battery electrical power system is the only totally new subsystem aboard the NASA MOL; its characteristics are shown in Figure 2-5. Rollout drums were selected over a fixed array because of packaging, weight, and cost considerations. Two-axis gimballing, utilizing dual-drive motors on common gears, provides redundancy and high reliability for 1-year of operation.

The Support Vehicle shown in Figure 2-6 is also identical to the baseline MOL in external geometry. The forward unpressurized compartment houses the additional propellant tankage to perform the rendezvous and docking operations as well as attitude control functions for the orbital configuration. A total of nine sets of propellant tanks are required for these operations.

The pressurized compartment contains living quarters for the four crew members. Private sleeping compartments are provided along

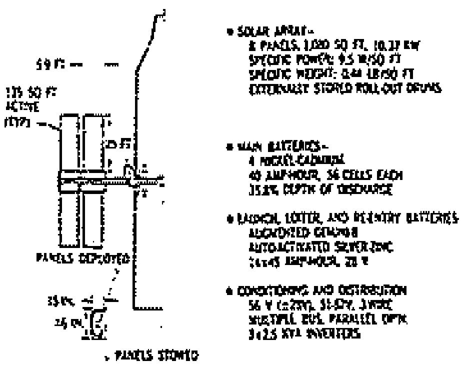

Figure 2-5. Solar Panel/Battery Power System

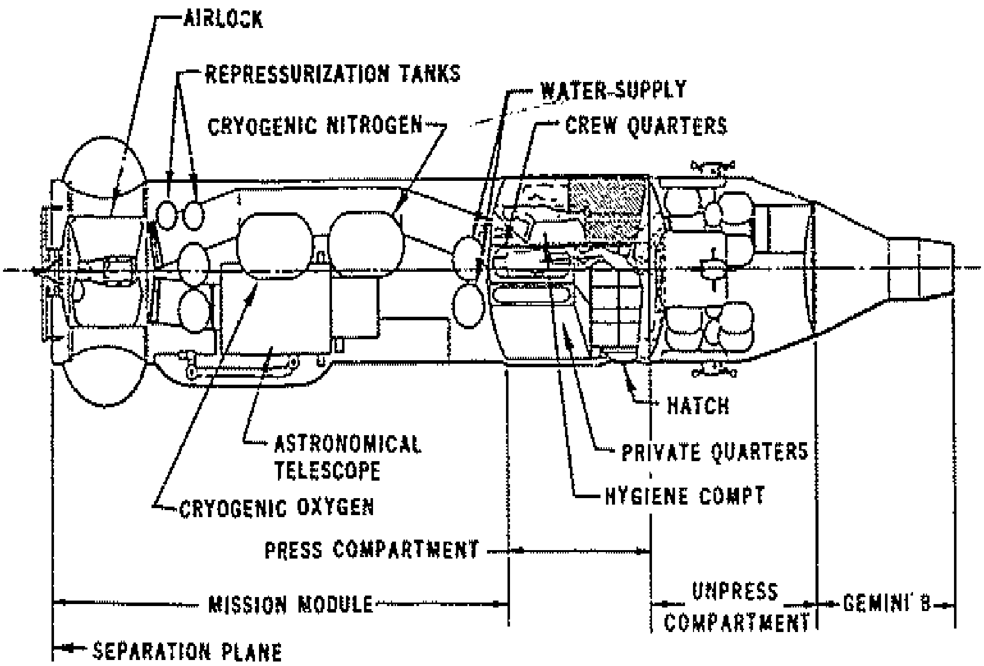

Figure 2-6. Double MOL Support Vehicle

with a galley, wardroom, and hygiene facilities. A minimum of hardwall construction is used in conjunction with a birdcage structure which contains provisions for connecting the softwalls used to divide the volume as desired. Of the approximately 1,000 cu ft volume available, 500 cu ft (one-half) is devoted to the private sleeping compartments.

The crew quarters in conjunction with the operational compartment in the Laboratory Vehicle provide a two-compartment emergency capability for the MOL station; in event of an emergency in either compartment the entire crew can inhabit the other compartments while the damage is assessed and/or repairs are made or until an abort decision is reached. Duplicate laboratory controls and adequate EC/LS capability are provided to support station operation from either of these compartments.

The mission module configuration is similar to that of the Laboratory Vehicle. The aft airlock, however, provides the added function of being an aft-docking control station. One crewman transfers there from the Gemini during the rendezvous maneuver and controls the docking maneuver. The stores contained in the mission module consist of cryogenically stored oxygen and nitrogen for the atmosphere, food, water, and experiments. Removal of the fuel cells and, therefore, the water supply from the baseline MOL requires that all the crew's water be orbited with this vehicle; 80% of this water is brought up in tanks and 20% in the form of wet food.

Experiments are provided as prepackaged equipment and may include one or more large modules. A 38-in. GEP-type telescope module is illustrated; manned access to the telescope is through a tunnel extension of the aft airlock, permitting changing of film pack and some maintenance in a shirtsleeve environment. The telescope is deployed on a boom and operates semi-independently from the vehicle.

Key modifications to the Air Force MOL required to satisfy the mission objectives in their approximate order of importance are as follows:

1. The solar panel battery electrical power system which has a major impact on the development program is a program-pacing item on the critical path.

2. The 6-month to 1-year cryogenic gas storage system is also a program-pacing item. If NASA accomplishes their present plans to develop such systems for AAP, they will be directly applicable to this mission.

3. The rear-end docking system is a new design, but is not considered a major development risk.

4. Substitution of Apollo communications equipment is required for compatibility with the MSFN. Modified Apollo equipment will satisfy the mission requirements.

5. The ACTS/PROP. system requires added thrusters and tankage. Lifetime extensions beyond 1-year will require propellant management to avoid stress corrosion problems.

2.3.2 Saturn Workshop/MOL Configuration/Mission

A mission profile for the Saturn Workshop/MOL configuration is indicated in Figure 2-7; it combines two suitably modified MOL vehicles with advance spent-stage workshop.

The advance spent-stage workshop, including an airlock and multiple docking adapter, is put into orbit by a Saturn IB vehicle using the apogee circularization technique previously discussed. It goes into orbit unmanned but with a payload of expendables to support subsequent MOL crews; it also contains the solar panel/battery power system capable of supplying the MOL's which will subsequently dock with it.

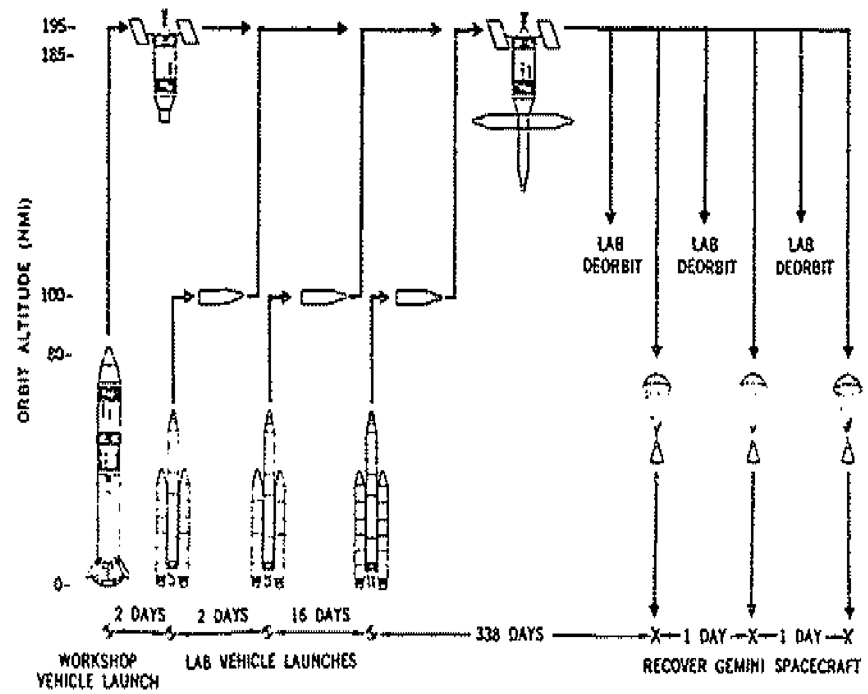

Figure 2-7. Mission Profile – Saturn Workshop/MOL

Three subsequent launches of modified MOL vehicles are accomplished by Titan III-M boosters; each of these launches is manned carrying a crew of two men in the Gemini B, a moderate supply of expendables, and an extensive experiment package. After rendezvous of the four vehicles, the indicated orbital configuration has the capability of remaining in orbit for the entire 1-year period. At the end of the mission the 6-man crew returns home in the three Gemini B's.

The Saturn Workshop/MOL configuration (Figure 2-8) uses a spent-stage workshop which is a growth version of that used for the AAP cluster mission and is capable of extended stay in Earth orbit. The solar panel installation indicated at the rear of the vehicle and the interior floors are major structural facilities which are launched in the wet stage. Outfitting of this stage for crew usage and/or experimental functions is required by the astronauts after they rendezvous with the workshop.

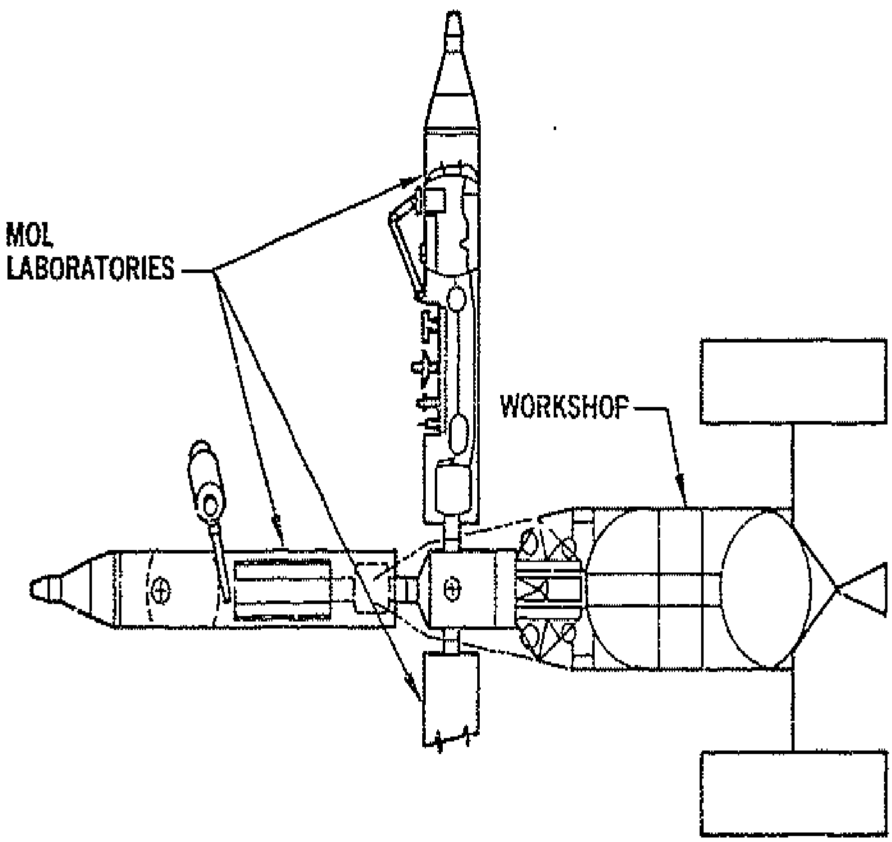

Figure 2-8. Saturn Workshop/MOL

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The airlock/expendable storage system shown at the front end of the tank provides access to the spent stage and contains expendables for the year's mission; tankage is provided for cryogenics, water, and propellants. The multiple docking adapter, shown on top of the airlock, provides the presently designed Apollo-type docking facilities to the MOL, which have rear-end Apollo type docking gear.

The three MOL laboratories docked to the workshop have a configuration similar to the Double MOL Laboratory Vehicle. They provide combined operational/experimental controls with minimal crew support quarters in the basic MOL pressurized compartment. The crew has access to the workshop for sleeping, hygiene, exercise, relaxation, and large-volume experimentation.

Each MOL laboratory is launched with its own experimental payload and with a crew trained specifically for those experiments. The power and cryogenic EC/LS are supplied by the workshop; thus, only batteries for minimal power and drinking water are carried aboard the MOL.

Shirtsleeve access is available at all times between the three MOL's with the airlock being used as a safety bulkhead to the workshop; thus, two-compartment safety is provided with the workshop considered as one compartment and the three MOL's plus the docking adapter the second compartment. Significant potential flexibility is attainable with the Saturn Workshop/MOL configuration by operating one of the MOL's in a deployed mode for a critical experimentation. Advantages to be gained from this mode which is shown in Figure 2-9 include (1) isolation from the disturbances of the main laboratory, (2) isolation from the electromagnetic radiation of the main laboratory, (3) isolation from the potential efflux field of the main laboratory caused water and EC/LS dumpage and leakage and propulsion system operation, and (4) the availability of orientations which would be more expensive to acquire using the main laboratory.

The MOL vehicle design includes adequate battery-supplied electrical power and ECS storage for approximately 24-hour operation in this deployed mode.

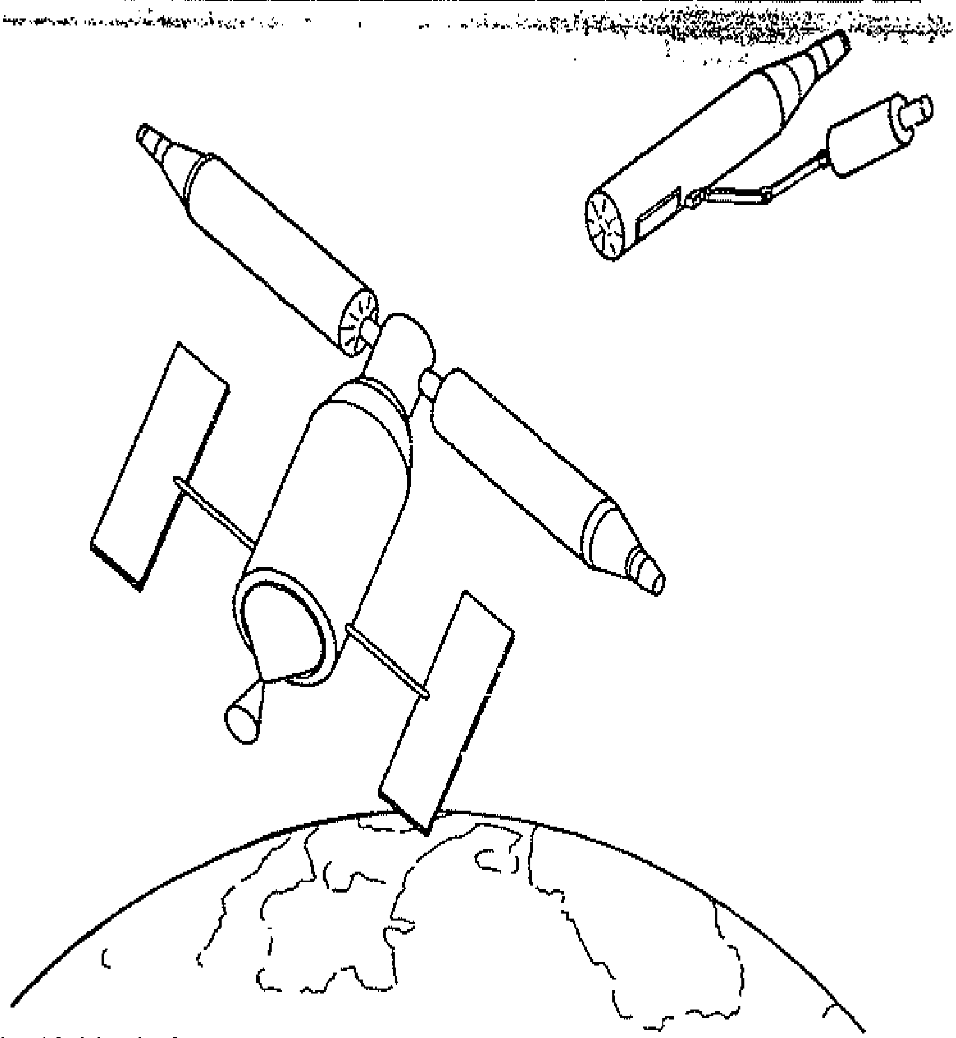

Figure 2-9. Independent Operations

Further flexibility can be provided by the Workshop/MOL through replacement of any MOL with one containing either a new experimental program, or a new crew, at any time.

2.3.3 Mission Core Module Configuration

While investigations on the Mission Core Module were not carried to the same depth as the configurations previously discussed, an orbital configuration was derived to assist in assessing this approach. The basic core module, or engine room (Figure 2-10) is 260 in. in diam, contains the MOL subsystem and subsystem component hardware equipment, and provides the basic operational control and crew living quarters. It is powered by a solar panel/battery electrical power system and contains atmospheric and propellant stores in an external rack. A six-man crew is brought aboard by

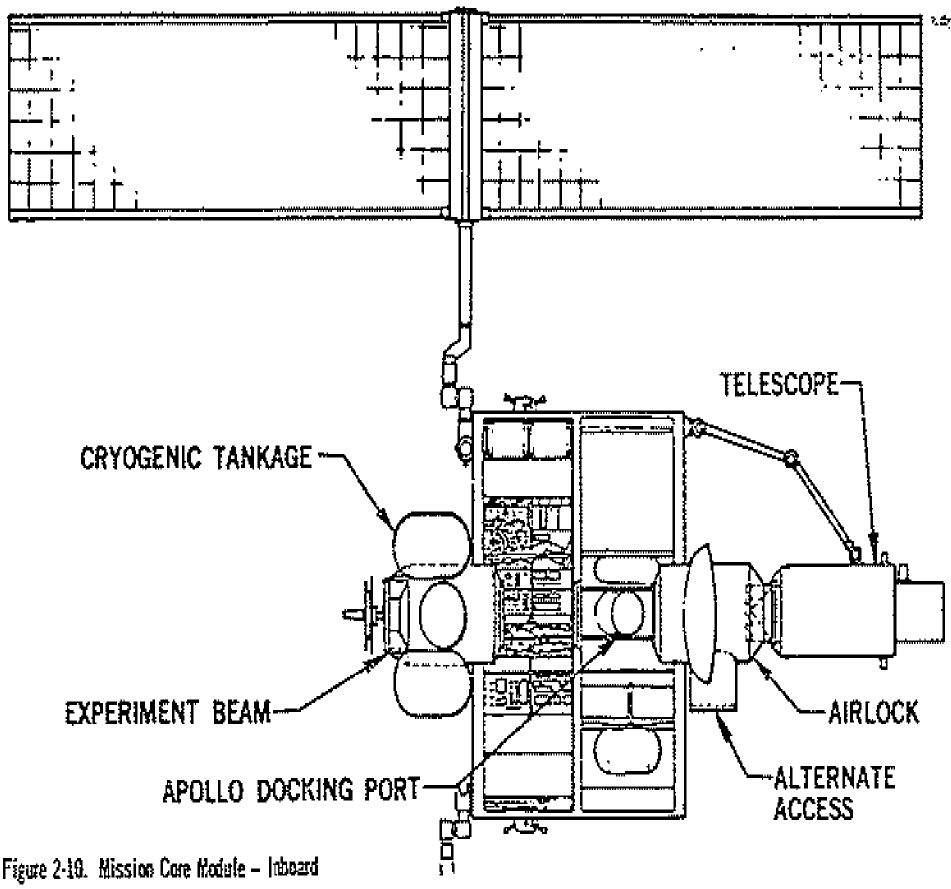

Figure 2-10. Mission Core Module – Inboard

two Apollo CSM vehicles which are docked to the station. The second module provides the docking equipment and contains the crew quarters. It is separated from the core module by an airlock and thus provides the second compartment safety for this configuration. Initial launch of the space station is accomplished with the Saturn V launch vehicle with sufficient expendables for the duration of the 1-year mission.

A section through the Mission Core Module (MCM) is shown in Figure 2-11. The basic features identified with the MCM (center access, flat bulkheads with tension ties, and accessibility to all equipment) are retained. For the MOL application equipment packaging associated with the MOL birdcage structure was retained wherever possible. The equipment panels and racks are offset from the walls providing access for meteroid inspection. Since the selected orbit does not impose a radiation problem, this approach is acceptable. Compartmentation then is possible using the equipment structure as a wall. Provisions for a liquid/micro-bio compartment (wet lab),

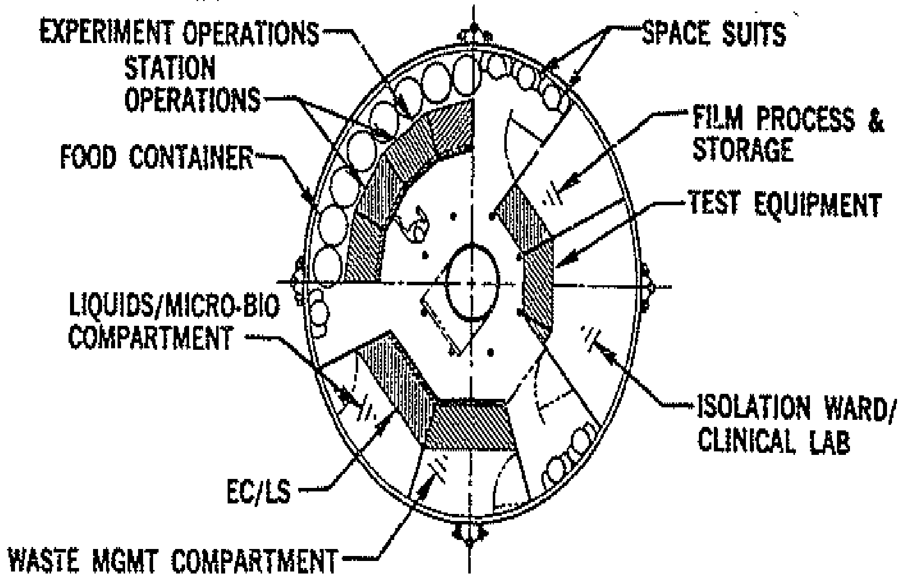

Figure 2-11. Mission Core Module

an isolated ward, film-processing compartment, and the waste management compartment are provided. Retention of a central control station for station operations is also provided.

In reviewing MOL equipment for the applicability to the MCM, emphasis was placed on identifying major subsystem elements rather than on a component level. The major applicable items are listed below.

1. EC/LS
    - A. Waste management.
    - B. Contaminant control.
    - C. Humidity and temperature control.
    - D. Thermal control unit.
    - E. Regulated oxygen supply.
    - F. Pressure control.
    - G. Ventilation system components.
2. RCS--All components.
3. Crew System--Selective equipment.
4. SCS
    - A. Horizon sensors.
    - B. Gyro packages.

C. Interface and display electronics.

D. Monitor and switching assembly.

5. Vehicle Electronics--Data management.
6. Electrical Power and Structures--None.

2.4 REQUIREMENTS ANALYSIS

In selecting the orbit parameters for the NASA mission, cognizance was taken of the fact that the biomedical/behavioral program is insensitive to orbital altitude and inclination and that a due East launch from KSC would produce the largest discretionary payload. This was balanced by the desire of experimenters to include broad Earth coverage, and hence, a high inclination. Figure 2-12 depicts the loss of payload resulting from various inclinations achievable from a KSC launch; the width of these curves include the Titan III-M, the uprated Saturn I, and the Saturn V launch vehicles. Range safety constraints limit in-plane launches to less than 50°.

Higher inclinations require doglegging at a considerable expense. A polar orbit may also be achieved by launch on a 146° azimuth with a dogleg to the west and south; this trajectory overflies Cuba and Panama.

A 50° inclination orbit with payload degradation of 3 to 6% (depending on the launch vehicle) was considered a reasonable penalty to pay for the added Earth coverage and was selected for this mission.

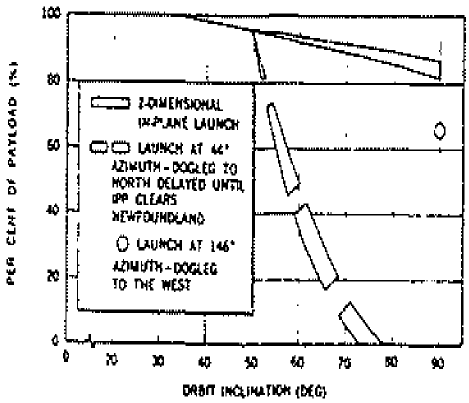

Figure 2-12. Effect of Orbit Inclination

Figure 2-13 presents the payload capabilities of the Titan III-M and the uprated Saturn I for both direct ascent and apogee injection. A payload advantage of 6,800 lb is gained for altitudes near 200 nmi by use of the apogee injection technique. Since investigation indicated that the MOL propulsion system is capable of accomplishing this maneuver without modification, apogee injection was chosen for this mission.

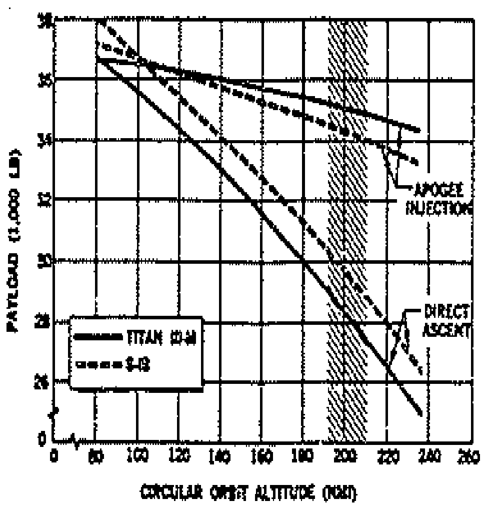

Figure 2-13. Launch Vehicle Payload Capability

Altitude selection was accomplished considering the total number of launches involved in the mission. Figure 2-14 presents the total useful payloads (payload minus propellant) available at various altitudes within the range of interest. Since propellant requirements for attitude control and orbit keeping are greater at lower altitudes, the curves tend to be flat over a broad range and an optimum altitude is not easily identifiable. Consideration of secondary benefits are thus in order. Requirements for rendezvous and experimental benefits from repeatable traces point to subsynchronous altitudes. At approximately 275 nmi, a circular orbit at 50° inclination repeats its ground trace daily. At 164 nmi and 218 nmi, the period is every 3 days; a 195-nmi orbit provides a 2-day subsynchronous altitude.

The 275-nmi orbit is eliminated because it requires requalification of the Gemini B heat shield and produces a more-severe radiation environment; the 164-nmi orbit requires about 3,000 lb more RCS propellant over a year's mission than the 195-nmi orbit and is also rejected. The selected orbital parameters for the mission are 195 nmi at 50° inclination.

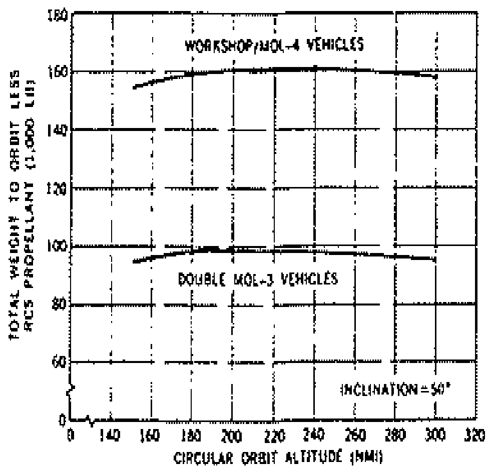

Figure 2-14. Altitude Optimization

For the selected orbit, a comparison of the environment requirements and the capabilities afforded by the baseline MOL without structural modification are presented in Table 2-2. It can be seen that the basic structure offers sufficient protection from the meteoroid environment to meet NASA criteria and that the radiation levels experienced inside

Table 2-2
MISSION REQUIREMENTS VERSUS MOL CAPABILITY

	REQUIREMENTS		CAPABILITY
METEOROID SHIELDING	P (SI) = 0.999		P (SI) = 0.9993
RADIATION SHIELDING	MAXIMUM ALLOWABLE DOSE (RAD)		TOTAL RECEIVED (RAD)
	EYES	270	27
	SKIN	400	28
	BFO	100	14
THERMAL CONTROL	NO CONDENSATION		DEW POINT: 50° TO 60°
	TEMPERATURE WITHIN COMFORT ZONE		AIR TEMPERATURE: 65° TO 80°
			WALL TEMPERATURE: 70° TO 90°

the vehicle are an order of magnitude lower than the allowables. Thermal control requirements are also met with the baseline EC/LS radiator design.

The major concern over mission accomplishment is the ability of the MOL equipment to operate satisfactorily over the 1-year mission. Basic MOL subsystem data were obtained along with data on spares optimization. Consideration was given to design changes and their effect on subsystem reliability. In some cases, reliability was improved through the addition of further redundancy; in others, a decrease of reliability was experienced. The resultant vehicle reliabilities are indicated in Figure 2-15 which presents the mission logic model for the Double MOL. One backup vehicle is provided for the Laboratory Vehicle and one for the Support Vehicle. A mission success probability of 0.923 is indicated for completing the biomedical behavioral program. The 0.978 mission survival probability indicates the expected ability of the Double MOL to continue the mission for 1 year even though failures are experienced and the experimental objectives may be compromised. These results provide confidence in this design approach.

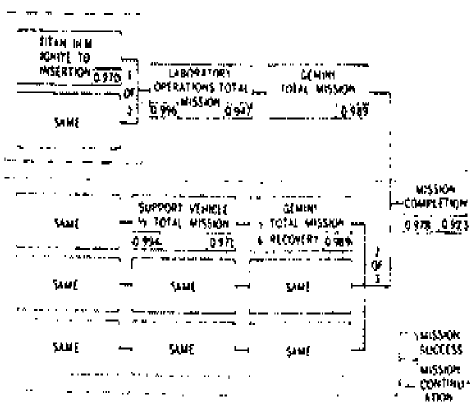

Figure 2-15. Mission Success Probability – Double MOL

2.5 EXPERIMENT RESPONSIVENESS ANALYSIS

It was specified by the customer that the S-IVB station module experiment program being prepared by Douglas for MSFC was to be used to assess the responsiveness of the MOL derived space stations. This program is summarized by major category in Table 2-3.

Military Uses of Space: 1946-1991

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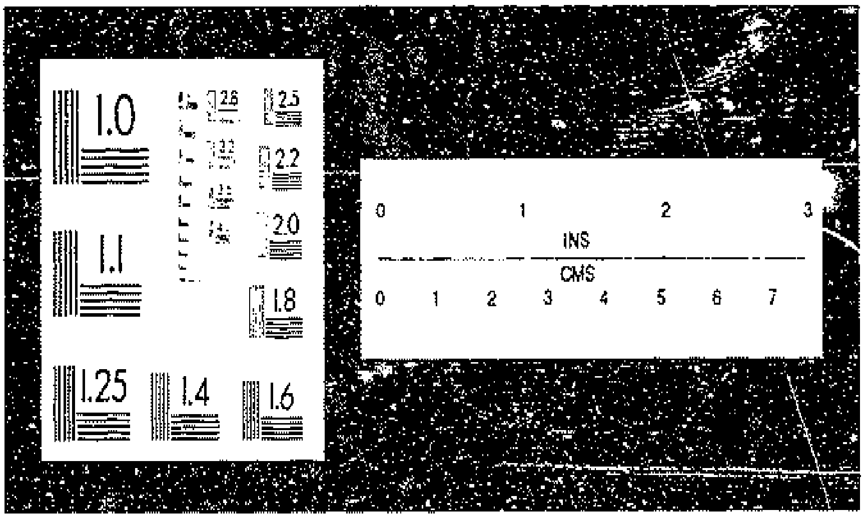

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Table 2-3
S-IVB SM EXPERIMENTS

TECHNOLOGY	NO. OF EXP
BIOMEDICAL BEHAVIORAL	36
ASTRONOMY/ASTROPHYSICS	17
ATMOSPHERIC SCIENCES	19
EARTH RESOURCES	[illegible]
BIOSCIENCE	[illegible]
PHYSICAL SCIENCE	[illegible]
COMMUNICATION NAVIGATION	1
ADVANCED TECHNOLOGY	[illegible]
OPERATIONS AND LOGISTICS	[illegible]
TOTAL	191

Because biomedical/behavioral assessment of man was the primary objective of the defined MOL mission, special emphasis was placed in this area. In lieu of an approved NASA biomedical/behavioral program, Douglas decided, through the use of senior consultants and literature available in this area, to select a representative program for this effort. This program has been reviewed by various NASA medical personnel and has their concurrence as to its appropriateness. The selected approach involved designing an integrated equipment installation to support this program which was capable of providing maximum data with minimum impact on the stations resources, that is, weight, power, volume and crew time and skill in involvement.

Figure 2-16 illustrates the installation of the various console panels and equipment required. At the present time, an integrated performance tester (COMPARE) exists in prototype form and is being evaluated by Wright-Patterson Air Force Base personnel. The visual/auditory tester and the physiological and biochemistry units have been designed and will be breadboarded at Douglas. The tester and units will be available in the near future for preliminary evaluation.

Douglas feels that this approach to the biomedical/behavioral program, which was defined and delineated on Douglas's independent research and development (IRAD) funds, offers a significant capability which will be available at an early date; in addition, it is felt that the efforts undertaken are adequately founded and have a sufficiently broad base for adaptation to NASA's final program when it is selected.

The remaining 155 experiments from the list of 191 are in engineering and scientific categories and were individually examined. Only one experiment, involving a 260-in. diam centrifuge, could not be physically accommodated.

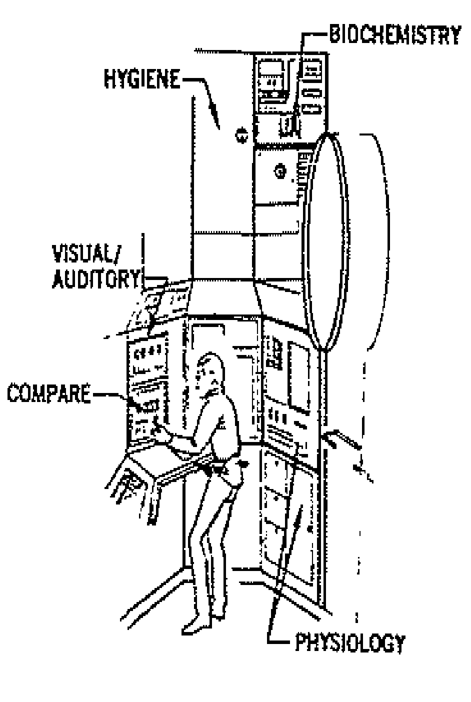

Figure 2-16. Biomedical Behavioral Installation

Two other communication experiments required an orbital altitude below the F_2 layer, and therefore, could not be satisfactorily performed. Nine experiments required orbit inclinations greater than 50°, which has been shown to be the practical limit for a KSC launch; these experiments could, however, be partially accomplished. Thus, 179 out of 191 or about 94% of the experiments listed could be fully accommodated singly and all but three, or about 98% could be partially accomplished. To derive a typical experimental program which could be accomplished on-board the spacecraft, the total experiment bank was examined from a critical parameter standpoint. Table 2-4 presents the experimental requirements, by critical parameter, and indicates the required laboratory capability with each parameter. Crew time availability appears to be adequate; however, there is a crew skill limitation in the Double MOL configuration associated with the four-man crew. The S-IVB SM list identifies the requirement for five crew skill categories, each of which consists of several skills. It is reasonable to assume that one category would be assigned to each crew. Therefore, only 4 of 5 or 80% are met by a 4-man crew. Realistic scheduling of the experiment program and a realistic assessment of the crew time usage will lower these estimates; based on past experience, a 70% to 75% responsiveness in the crew time/skill category can be expected.

Table 2-4
FACILITY EXPERIMENT CAPABILITY

	AVAILABLE		% ACHIEVED AVG	
	DOUBLE MOL	WORKSHOP MOL	DOUBLE MOL	WORKSHOP MOL
CREW TIME	[illegible]	[illegible]	[illegible]	100
CREW SKILL CATEGORIES	4	[illegible]	80	100
VOLUME	[illegible]	[illegible]	100	100
POWER	[illegible]	[illegible]	[illegible]	100
WEIGHT	14 260 LBS	[illegible] LBS	[illegible]	[illegible]

As indicated, no problem exists in supplying adequate volume or packaging experiments for transit to orbit nor for supplying power to these experiments. Although the S-IVB spent-stage workshop will offer an additional large pressurized volume in orbit, it is not usable for getting the experiments into orbit. On the average, the weight responsiveness appears to be a limiting factor; however, an examination of the experimental weight-distribution curve indicates a significant bimodal nature with a large group of experiments of very low weight and a significant group of very high weight. Thus, it is possible to maximize the effectiveness of accomplishing the experiment program by being selective as to what equipment is on-board.

Table 2-5 presents the experimental package weights by technological category (previously defined); it also indicates the individual weights of all experiments above 1,000 lb. An examination of the high-weight items indicates several have "high utilization", that is they support several experiments. For instance, the 38-in. telescope is used in a total of 6 experiments; thus, a premium may be placed on carrying it to get the broadest experimental program capability.

Table 2-5
WEIGHT BY EXPERIMENT CATEGORY

TECHNOLOGY	WEIGHT (LBS)	WEIGHT ABOVE 1000 LBS	% TOTAL NO. EXP.
BIOMED-BEH	384	—	18.5
ATMOSPHERIC SCIENCES	1,940	—	9.1
EARTH RESOURCES	1,306	—	5.2
PHYSICAL SCIENCES	1,143	—	11.0
MANNED SPACE OPER	8,235	—	14.0
DATA CAPSULE		2,000	
CREW ESCAPE		2,000	
ASTRONOMY	9,900		9.9
32" SOLAR		2,000	
38" TELESCOPE		1,000	
SKY SURVEY & RAY		6,000	
BIOSCIENCE	2,356		18.0
MAMMAL SUPPORT		2,000	
COMM, NAV. & TRACKING	3,335		5.7
MICROWAVE EQUIP		1,000	
LASER ALTIMETER		1,000	
ADVANCE TECH.	3,345		8.2
DATA CAPSULE		2,000	
SUB TOTAL	31,734		
WIRE, PANELS, ETC	9,600		
TOTAL	41,334		

Based on this background, it is now possible to select typical programs and evaluate their overall usefulness. Program No. 1, indicated on Table 2-6, is strictly a minimum-weight program; that is, it begins at the lowest weight end of the ranked experiment list and moves up the list until the total weight allocation has been used; this weight includes a 33% factor above the basic experiment program weight for installation, wiring, and control panels. Interestingly enough, Program No. 1, even though a minimum-weight program, not only covers all the categories

Table 2-6
TYPICAL PROGRAM SELECTION – DOUBLE MOL

	PROGRAM 1	PROGRAM 2
BIOMEDICAL/BEHAVIORAL	36/36	36/36
ASTRONOMY	4/17	10/17
ATMOSPHERIC SCIENCES	19/19	17/19
EARTH RESOURCES	25/26	25/26
BIOSCIENCES	33/33	33/33
PHYSICAL SCIENCES	19/19	10/19
COMMUNICATIONS, NAVIGATION, AND TRACKING	4/9	5/9
ADVANCED TECHNOLOGY	15/16	15/16
MANNED SPACE OPERATIONS	9/16	9/16
TOTAL	164/191	160/191
	86%	83.8%

but covers most of the major categories quite well. It is weak primarily in astronomy, communications and navigation and tracking. However, it represents a weight responsiveness greater than 85% of the S-IVB SM experiment list.

Program No. 2 was synthesized to put more emphasis on astronomy than on physical sciences. Again, a quite reasonable distribution of experiments across the technologies is achieved and a weight responsiveness in excess of 80% is attained.

Preliminary data presented in Figure 2-17 indicate that monumental efforts and significant funding would be required to have 120 experiments, or 60% of the total considered, available for 1971 launch. This assumes, of course, availability of adequate funding and of adequate experiment definition in the immediate future.

Thus, although it is recognized that the programs presented are not totally realistic at this time, because priorities and equipment availabilities have not been fully assessed, it is felt that the results of the study indicate a high potential of accomplishing an experimental program of major significance on-board the NASA-MOL stations.

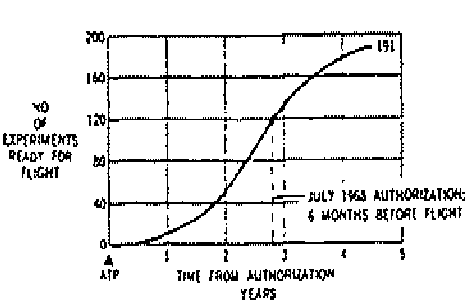

Figure 2-17. Experiments Availability-191 Experiments

Section 3
PROGRAM DEFINITION

Table 3-1 indicates usage of NASA and contractor facilities by the MOL derived space station program defined. Analyses performed together with the Douglas MOL Program personnel indicate that existing MOL facilities and equipment for manufacturing and subassembly of the NASA space station could be made available without interference to the Air Force MOL program. For integration and checkout of the laboratory and mission modules, a new high-bay facility and a space chamber would be required at the Douglas Huntington Beach location; cost of these additional facilities is estimated to be less than $20 million.

Before shipment from the factory, the entire MOL vehicle is assembled in the high-bay area and is completely checked out. It is then transported to the KSC industrial area for removal of the prototype experiment packages and installation of the qualified hardware. Final inspection before delivery to NASA occurs at this facility.

The flight vehicle would be delivered to, and assembled in, the Vertical Integration Building (VIB) of the T-III M complex and would be functionally tested; the addition of environmental shelters in the VIB would be required. Existing AGE equipment in the VIB would be used to check out the T-III M and a hardline between the VIB and the NASA O&C building would allow checkout of the payload using the NASA equipment; new software would be required for this activity.

To eliminate modifications to the Solid Motor Assembly Building (SMAB) and to the vehicle transporter, only five of the seven segments of the zero stage would be installed in the SMAB. The remaining two segments would be added to the vehicle on the launch pad; this could be accomplished in a few hours.

Table 3-1
FACILITIES UTILIZATION

MANUFACTURE & C/O	
• FABRICATION	EXISTING
• ASSEMBLY	EXISTING
• INSTALLATION & EXPERIMENT INTEGRATION	NEW
• SPACE CHAMBER	NEW
PRE-LAUNCH	
• EXPERIMENT INSTALLATION C/O	NEW OR MODIFIED
• VIB	MODIFIED
LAUNCH	
• SMAB	EXISTING
• PADS (40 & 41)	EXISTING
MISSION CONTROL	
• MOCR	EXISTING
• OOCR	NEW
• EXPERIMENT DATA REDUCTION	NEW
• COMPUTER COMPLEX	MODIFIED
• TRAINING & SIMULATION	NEW

Both Launch Pads 40 and 41 are used for either space station configurations. Only minor modifications including extension of the flame deflectors and changes to the work platforms are required.

MSC's advance study efforts have identified the need for two additional Sustained Operation Control Rooms for use in the 1970 time period. These facilities would be used to control long-duration missions supplying both critical phase and orbital operations support; they would thus supply the requirements for a MOCR and an Orbital Control Room (OCR) facility. If these installations are not available by the time this mission is undertaken, sharing of existing facilities appears feasible; in this event, an added orbital control facility would be required and mission-critical phases would be handled by one of the existing MOCR's. Additional experiment support, training, simulation, and computation capability are also required.

A program implementation summary is presented in Figure 3-1. Special emphasis was placed on providing a detailed program definition for the NASA-MOL configurations. Together with Douglas MOL project personnel, schedules, cost, and manufacturing aspects were investigated in depth to ensure NASA of a meaningful assessment of the availability and potential cost of such a program.

To determine the vehicle launch date, the sequence of activities preceding the development and operations phase had to be estimated. The current study phase is considered equivalent to a NASA Phase A, feasibility study. A 3-month evaluation of these is allowed, resulting in start of a 9-month combined Phase B/C study in January 1968. If another 2 months are allowed from the October completion date for evaluation of those results, a Phase D ATP could be postulated as early as December 1968.

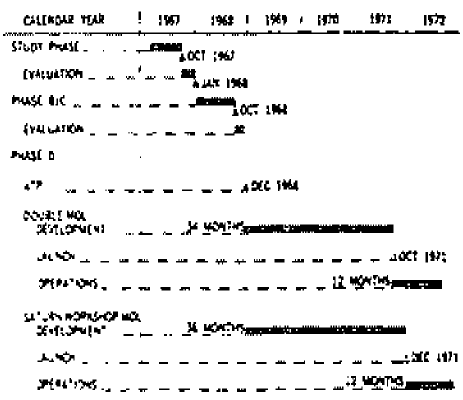

Figure 3-1. Program Implementation

The timing of these efforts is under the complete control of NASA and, of course, the budgetary constraints imposed upon them by the Congress. If these dates are met, Douglas is confident that the rest of the program can be achieved as indicated. That is, a Double MOL mission could be launched 34 months from ATP of Phase D, or alternately, a Saturn Workshop/MOL mission could be launched 36 months from ATP of Phase D; both these launches are in calendar year 1971.

The critical path for the development phase is indicated in Figure 3-2. This path proceeds through the Phase B/C study during which the cryogenic gas storage and electric power system subcontractors would be selected, and

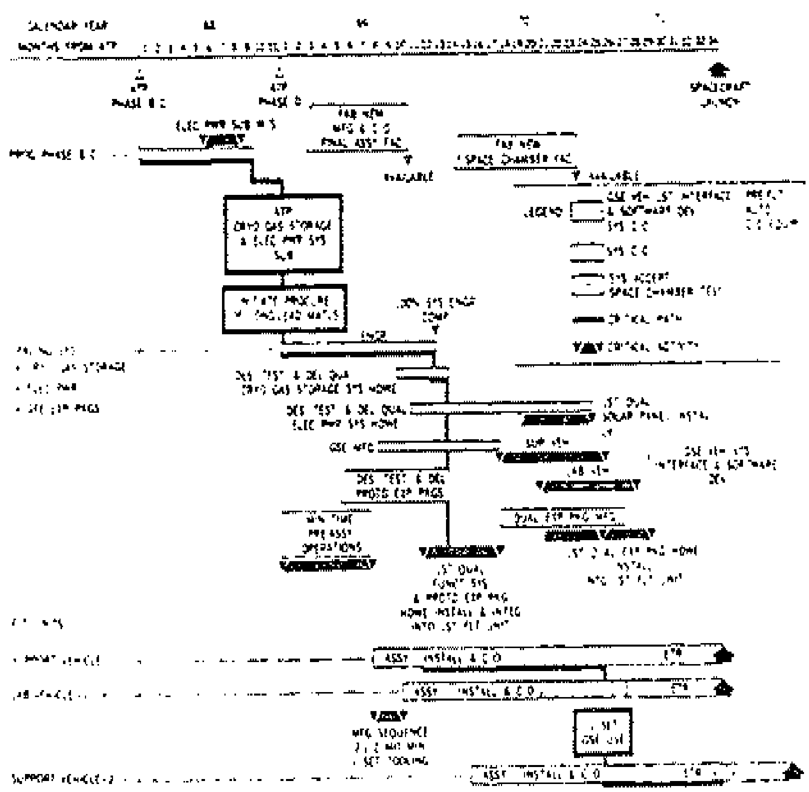

Figure 3-2. Double MOL Critical Program Activities

preparations for initiating procurement of long leadtime materials accomplished. In Phase D, the path follows the 12-month engineering program, the design, test, and delivery of qualified cryogenic gas systems and leads in the functional test of the prototype experimental package. After integration of the functional systems and prototype experimental hardwares into the first flight unit, the critical path moves through the availability of GSE to Support Vehicle checkout.

Several critical activities which could affect the program and become part of the critical path if not given proper attention are also indicated. One of these key items is the qualification of the solar panel installation; a second is the GSE vehicle system checkout interface and the development of software necessary to support this activity; and a third is qualification and installation of the experimental packages into the flight vehicle.

It should be noted that prototype experiment equipment is installed at the factory to support the laboratory integration/checkout activities. The flight-qualified experiments are substituted for the prototypes after delivery of the flight vehicle to KSC; this allows the maximum time for development of these equipments.

Major costs are presented by non-recurring and recurring elements in Tables 3-2 and 3-3; the DDT&E costs, less experiments, are $556 million and $839.3 million, respectively. These represent the most meaningful costs for comparison to other 1-year space station concepts as all other items will be approximately the same regardless of the concept chosen. The total program costs for a 1-year mission indicated in Table 3-4 are $2.383 and $2.876 billion for the Double MOL and Saturn Workshop/MOL, respectively.

Table 3-2
PROGRAM COST
NON-RECURRING MILLIONS OF DOLLARS

PROGRAM ELEMENT	DOUBLE MOL	WORKSHOP/MOL
LAB/SUPPORT VEHICLE	169.8	135.5
GEMINI B	99.5	79.7
WORKSHOP	——	158.2
LAUNCH VEHICLES		
• T III M	85.3	68.2
• SIB	——	44.2
FLIGHT CREW PROJECT	116.6	116.6
EXPERIMENTS	360.0	350.0
MISSION OPERATIONS	102.2	102.2
PROGRAM MANAGEMENT	151.9	173.3
TOTAL	1,085.3	1,237.9

Table 3-3 non
PROGRAM COST RECURRING
MILLIONS OF DOLLARS

PROGRAM ELEMENT	DOUBLE MOL		WORKSHOP/MOL	
DDT & E	756.0		1,039.3	
• LAB SUPPORT VEHICLE		462.5		396.5
• GEMINI		92.5		92.5
• SPENT STAGE		——		359.3
• EXPERIMENTS		200.0		200.0
• LAUNCH VEHICLE		1.0		1.0
FLIGHT CREW PROJECT	177.3		176.3	
MISSION OPERATIONS	14.1		14.1	
FACILITIES	169.1		179.1	
PROGRAM MANAGEMENT	181.8		229.3	
TOTAL	1,298.3		1,638.1	

Table 3-4
PROGRAM COST TOTAL

	DOUBLE MOL	WORKSHOP/MOL
NON RECURRING	1,298	1,638
RECURRING	1,085	1,238
TOTAL	2,383	2,876

Section 4
CONCLUSIONS

The Double MOL and Saturn Workshop/MOL configurations are compared in Table 4-1. Either can begin orbital operations by the end of 1971. For the Double MOL there appears to exist a potential of extending the one-year mission to 18 months with the launch of a third Support Vehicle; estimates of mission success probability are quite high and if NASA implements this program, this growth potential should be pursued.

About 75% of the experiments to be performed are launched with the Double MOL laboratory and initial Support Vehicles. The remaining 25% arrive 6 months later. Approximately one-half of the experiments remain in orbit for the full 1-year period while the other half are in orbit for only 6 months. For the Workshop, all experiments are in orbit for the entire 1-year period.

The potential flexibility provided by the Saturn Workshop/MOL, which has the capability of operating separately from the cluster for periods of up to 24 hr., may be a significant advantage for some operations.

Table 4-1
CONCEPT COMPARISON

	DOUBLE MOL	WORKSHOP MOL
AVAILABILITY	1971	1971
PROGRAM COST	240	290
FLEXIBILITY		
DURATION	≥ 1 YEAR	1 YEAR
EXPERIMENTS	6 MOS 1 YEAR	1 YEAR
INDEPENDENT OPERATIONS	NO	YES
CREW SIZE	4	6
EXPERIMENT RESPONSIVENESS		
[illegible]	50%	100%
ENG SCI BEST CASE	55	82%

Both configurations accommodate not only the entire biomedical/behavioral program, but a significant portion (about 85% in a minimum weight case), of the engineering and scientific experiments.

The significant conclusions resulting from this study are presented in Table 4-2. We feel that feasibility of a 1-year MOL-derived space station has been established and that the 1971 launch of a NASA

Table 4-2
CONCLUSIONS

- A ONE YEAR MOL DERIVED SPACE STATION IS FEASIBLE
- 1971 LAUNCH IS ACHIEVABLE WITHOUT MOL SATURN PROGRAM INTERFERENCE
- SIGNIFICANT EXPERIMENT CAPABILITY FLEXIBILITY ACHIEVABLE 50 80% OF SIVB S.M PROGRAM
- DOUBLE MOL SPACE STATION RELATED COSTS APPROX $556M ONE YEAR PROGRAM $2,384M
- EARLY NASA DECISION & FUNDING REQUIRED
- EARLY EXPERIMENT DEVELOPMENT QUALIFICATION REQUIRED
- MOL SUBSYSTEM MODIFICATIONS REPLACEMENTS USE CURRENT TECHNOLOGY
- MINIMAL GEMINI MODIFICATIONS REQUIRED

mission using such equipment is achievable without interference with the on-going MOL and Saturn programs. However, an early NASA decision and program definition, and availability of funding for both the space station and experiment development, is required if this mission is to be operational by 1971; programmatically, it seems probably that such a date, while technically feasible, is unlikely to be achieved.

It is concluded that either of the MOL-derived space stations studied can accommodate 60% to 80% of the established S-IVB support module experiment program; it is not considered likely that any greater experiment definition/equipments will be available in this time frame.

The MOL subsystem modifications/replacements which are necessary for the long-duration mission can all be accomplished with current technology; in fact, only two items of critical schedule significance have been identified. These are the development of 6-month to 1-year cryogenic tankage and the development of a large-array solar-panel power system. Modifications to the Gemini and T III-M required to support the mission are minor and will cause no concern from either a schedule or risk standpoint.